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(33) US

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GB 2304760 A WO 98/34006 A1 WO 98/13572 A1

(58) Field of Search

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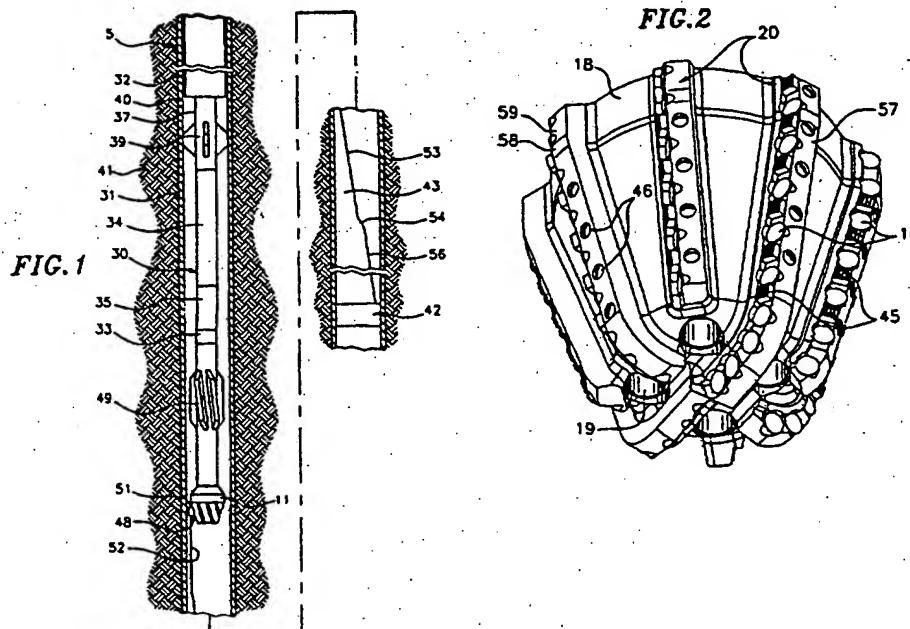
INT CL⁶ E21B

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(54) Abstract Title

Method for milling casing and drilling formation using a dual function drill bit

(57) A dual function drag bit 11 is used in a method for both milling well casing 40 or liner and subsequently drilling rock formation 41 without the sequential removal of a milling assembly and replacement with a drilling assembly. The method employs a cutting tool that is capable of both milling steel pipe casing in a well bore and subsequently drilling rock formation outside the well bore after passing through the casing. In one embodiment, inserts (16, figure 3) designed for embedding into the surface of a cutting tool 11 comprise at least an outer layer (22, figure 3), such as cemented tungsten carbide, capable of milling steel, and at least a second layer (23, figure 3), such as polycrystalline diamond, capable of drilling formation, the two layers being bonded together and to a carbide substrate (24, figure 3). In another embodiment, inserts 16 with a polycrystalline diamond cutting face for drilling rock formation are in parallel with cemented tungsten carbide cutters 45 for milling steel casing.



GB 2 335 217

FIG. 2

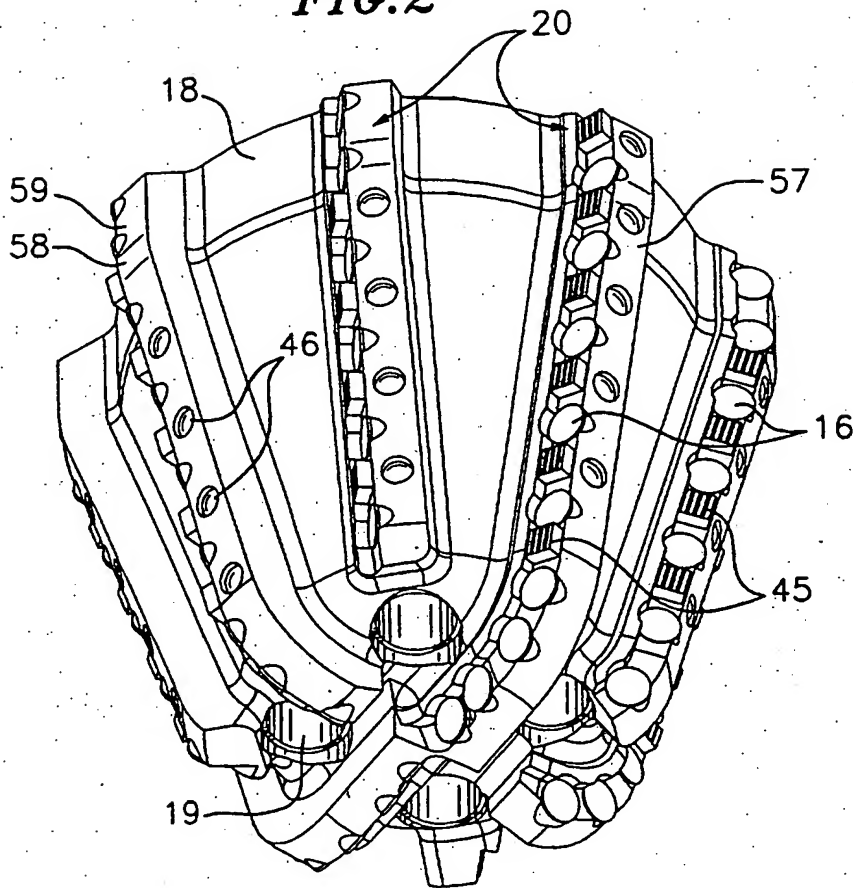


FIG. 3

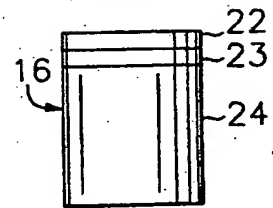


FIG. 4

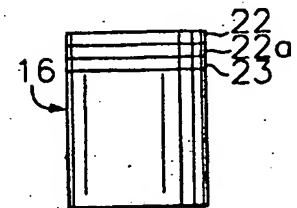


FIG. 5

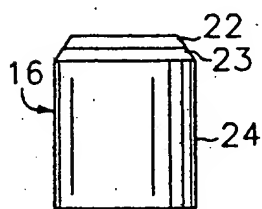


FIG. 6

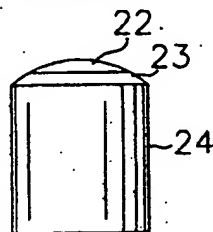
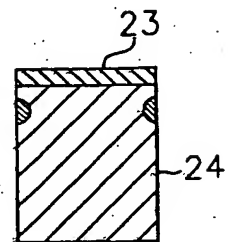


FIG. 7



1 disclosed system requires three trips into the well, beginning
with the creation of an initial window in the borehole casing,
the extension of the initial window with a particular cutting
tool, and the elongation and further extension of the window by
5 employing an assembly with multiple mills.

By integrating a whipstock into the milling operation and
directionally orienting the milling operation to a more confined
area of well casing, the number of trips required to effectively
mill a window in a well casing have been decreased. A whipstock
10 having an acutely angled ramp is first anchored inside a well and
properly oriented to direct a drill string in the appropriate
direction. A second trip is required to actually begin milling
operations. Newer methods integrate the whipstock with the
milling assembly to provide a combination whipstock and staged
15 sidetrack mill. The milling assembly is connected at its leading
tool to the top portion of the whipstock by a bolt which, upon
application of sufficient pressure, may be sheared off to free
the milling assembly. The cutting tool employed to mill through
the metal casing of the borehole has conventionally incorporated
20 cutters which comprise at least one material layer, such as
preformed or crushed tungsten carbide bonded to a carrier,
designed to only mill pipe casing. The mills used for milling
casing are not suitable for extensive drilling of rock formation.

Once a sufficient window has been created, the milling
25 assembly is removed and the drilling assembly is inserted into
the borehole and directed to the newly formed window to drill
earthen formation. Directional drilling is achieved by a number
of conventional methods, such as steerable systems, which, when
used, control borehole deviation without requiring the drilling
30 assembly to be withdrawn during operation.

A typical system may use a bottom hole motor with a bent
housing having one fixed diameter bit stabilizer below the
housing and one stabilizer above the housing in combination with
a measurement-while-drilling (MWD) system. Deviation is achieved
35 by using the motor output shaft to rotate the drill bit while

1 employ a method and incorporate the requisite devices which would
both mill a window in the original well casing and subsequently
drill formation through the newly created window in a single
step.

5 It would be desirable to provide a method and device which
enables the milling of pipe casing and subsequent drilling of
formation without requiring multiple trips.

10 The present invention employs a dual-function cutting tool
that is capable of milling pipe casing and/or liner and
subsequently drilling formation. An exemplary cutter embedded
in the cutting tool comprises at least a first material layer,
such as cemented tungsten carbide, capable of milling pipe casing
15 and/or liner and at least a second material layer, such as
polycrystalline diamond, capable of drilling formation, the two
layers being bonded together and to an insert body. The
thickness and configurations of the material layers relative to
each other and to the carrier vary and may include beveled and
20 twin edge constructions which vary the cutting surface and
improve the milling and drilling operation.

The cutting tool body is attached to a bottom hole assembly
that connects to the drill string. The cutting tool may be
optionally attachable to a whipstock to integrate the packing,
25 anchoring, and orienting of a whipstock with the insertion of the
milling and drilling assembly, thereby eliminating the need for
a separate whipstock placement trip.

The milling and drilling process is conducted by shearing
off the connection between the whipstock and cutting tool and
30 directing the dual function milling and drilling assembly down
the whipstock incline toward the well casing. After a window is
milled through the casing, directional drilling can then proceed
by any conventional method. The same cutting tool is used for
both milling the casing and drilling the rock formation beyond

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1 some level (referred to as a liner hanger point) below the ground
surface. Typically, either casing or liner is cemented in the
well bore with a cement grout. Since both are steel pipe and it
5 makes no difference for practice of this invention where the pipe
is suspended, the pipe is referred to herein simply as casing.

A preferred embodiment of an apparatus capable of practicing
the method of the present invention is shown in FIG. 1. A bottom
hole assembly 30 with a cutting tool 11 which has the capability
of both milling well pipe casing 40 and drilling earthen
10 formation 41 includes a series of tools 32-39 between the cutting
tool 11 and the drill pipe 31, described in greater detail
hereinafter.

Unlike conventional cutting tools, the cutting tool 11
employed in the present invention is multi functional in that it
15 is designed to both mill pipe casing 40 and subsequently drill
earthen formation 41. While the present invention is not limited
to any particular design for a multi functional cutting tool
capable of sequentially milling pipe casing and drilling
formation, an exemplary embodiment of the cutting tool 11 is
20 provided in FIG. 2.

In the embodiment shown in FIG. 2, the cutting tool 11, of
a form commonly referred to as a drag bit, comprises a body 18
with a threaded shank at the top (hidden in this view) for
connection to a bottom hole assembly 30. The body 18 may be
25 formed from steel or a tungsten carbide matrix infiltrated with
a binder alloy or any other material used in the art. Extending
outwardly from the base of the cutting tool body 18 are a series
of arched projections or blades 20 which comprise the cutting
tool surface and into which are embedded inserts or cutters 16.
30 Within the cutting tool body 18 are one or more passages ending
in openings 19 through which drilling fluid may be delivered to
cool the cutting tool surface and remove accumulated debris.

In the illustrated embodiment, the inserts 16 comprise 13
mm diameter cylindrical bodies of cemented tungsten carbide with
35 a layer of polycrystalline diamond (PCD) on an end face. Each

1 As an alternative to providing separate pieces of cemented
tungsten carbide on the face of the blades for cutting steel,
carbide can be provided on the face of some or all of the PCD
inserts. Such a layer of carbide can be used for milling steel
5 casing, and after the bit enters rock formation, the carbide is
eroded away leaving the PCD layer exposed for drilling rock
formation.

 As shown in FIG. 3, such an insert 16 comprises material
layers 22, 23 which are bonded onto a carrier substrate 24 and
10 then secured into the cutting surface of the cutting tool. As
stated previously, the material layers have conventionally been
designed to be mono-functional. The present invention uses a
first material layer 22 which is capable of milling pipe casing,
such as 9 5/8 inch steel casing, bonded to a second material
15 layer 23 which is capable of drilling earthen formation. The
type of metal used in the pipe casing and the type of geological
formation being drilled determine the materials to constitute the
first or outer layer 22 and second material layer 23.

 Materials such as polycrystalline diamond, polycrystalline
20 cubic boron nitride (PCBN), natural diamond, titanium nitride,
tungsten carbide or tungsten carbide cemented with cobalt can be
used in either the first layer 22 or second material layer 23,
as suitable for the intended functions of milling steel casing
or drilling rock formation, respectively. It is within the
25 knowledge of one skilled in the art to choose the proper
combination of material layers based upon the type of casing and
geological formations being encountered.

 If milling a 9-5/8 inch steel casing, a preferred embodiment
of the present invention employs a first material layer 22 made
30 of cemented tungsten carbide bonded to a second material layer
23 made of polycrystalline diamond. PCBN can be used in the
first material layer 22 but, relative to a milling grade of
tungsten carbide, it does not mill steel as effectively. Both
tungsten carbide and PCBN are preferred materials for the first
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1 and is dependent and determined by the expected wear profile.
One preferred embodiment, shown in FIG. 5, employs a beveled
structure where the first layer 22 substantially covers the
second layer 23 and both material layers 22, 23 cover the face
5 of the insert body. The beveled edge has an angle corresponding
to the rake angle of the insert mounted in the bit body. This
may improve the performance of the insert and minimize chipping.
For directional drilling, a rounded insert profile, shown in FIG.
6 can be used to attain sufficient side loading. Different
10 geometries of insert may be used in the gage rows and in inner
rows on the cutting tool.

The cutting tool 11 is used in conjunction with a bottom
hole assembly 30 which stabilizes the cutting tool, provides the
motive force for rotating the cutting tool, and after milling
15 through casing, directionally controls the movement of the
cutting tool in rock formation. While components of the bottom
hole assembly may be varied without exceeding the scope of the
claimed invention, the bottom hole assembly is described in
relation to an exemplary embodiment illustrated semi-
20 schematically in FIG. 1. It will be recognized that the relative
lengths and diameters of the parts of the bottom hole assembly
may be rather different from what is illustrated.

The bottom hole assembly 30 comprises drill collars 32, a
rotatable shaft 33, a bottom-hole motor output shaft (not shown),
25 bottom-hole motor 34, a bent housing 35, one or more stabilizers
39 and a connector sub 37. The cutting assembly includes cutting
tool 11 for milling casing and drilling rock formation as
provided in practice of this invention, and a second milling tool
49 above the cutting tool. The cutting tool 11 opens a window
30 through the casing in a well and the second milling tool enlarges
and cleans up the shape of the window. A third milling tool may
also be used if desired. The second and third milling tools are
conventional watermelon mills or window mills.

The cutting assembly connects to the bottom hole assembly
35 30 by connecting to the rotatable shaft 33 which, in turn, is

1 The bottom hole assembly can be connected to the whipstock
to both facilitate positioning and eliminate the requirement of
separate trips for positioning the whipstock and initiating
milling and drilling operations. The cutting tool 11 may be
5 connected to the top portion of the whipstock by a bolt 48 which,
upon application of sufficient pressure, is sheared off, thereby
releasing the bottom hole assembly from its fixed position
relative to the whipstock and permitting it to proceed down a
path toward the pipe casing defined by the inclination of the
10 face of the whipstock. The connection between the bit and the
whipstock may be hollow and/or connected via a port through the
body of the bit so that upon shearing off of the connection, the
port is opened and serves as a fluid port during the milling and
drilling operation.

15 The drag bit for milling casing and drilling adjacent rock
formation after a window is cut through the casing, is preferably
used with a whipstock having complementary surfaces, as described
in U.S. Patent Application Serial No. 08/642,829, assigned to the
same assignee as this application. The subject matter of the
20 pending application is hereby incorporated by reference.

In a typical embodiment, the whipstock has a ramp surface
with several different angles relative to the axis of the
borehole in which it is placed. At the upper end of the
whipstock there is a short surface 51 having an angle of about
25 15° which is useful for starting the cutting of a window. Just
below the starting ramp 51, there is an elongated surface 52,
which is parallel to the axis of the hole. The length of the
parallel surface is about the same as the distance between the
first cutting tool 11 and the second milling tool 49. Next,
30 going down the borehole, there is a ramp surface 52 on the
whipstock with an angle of about 3° from the borehole axis. The
3° surface continues until it reaches approximately the
centerline of the borehole. At that elevation there is a short
15° "kickoff" surface 54. Below the kickoff surface the face of
35 the whipstock reverts to a 3° angle.

1 3° portion of the cutting tool engages the 3° ramp surface 53 on
the whipstock, and is further forced laterally into the casing
and surrounding cement; gradually enlarging both the length and
width of the window through the casing. The watermelon mill
5 follows, cleaning up the window made by the cutting tool.

As the center of the cutting tool approaches a point where
it should be milling casing, the 15° portion of the cutting tool
engages the kickoff surface 54. This tends to force the cutting
tool laterally through the casing and surrounding cement at a
10 relatively rapid rate through the portion of the milling
operation where the center of the cutting tool is cutting the
steel of the casing. This is a part of the milling operation
where the rate of penetration is relatively lower and is desired
to proceed through this part rapidly.

15 After the center of the dual function cutting tool has
passed through the casing, the cutting tool engages the final 3°
ramp 56 on the whipstock and proceeds to enlarge the window
through the casing and extend further into the rock formation.
Meanwhile, the second milling tool 49 continues to enlarge and
20 clean up the window through the casing.

Typically, in the past, the sidetracking operation has
continued after the initial milling tool has passed through the
casing to produce a short rat hole in the formation adjacent to
the original borehole, which has sufficient length to accommodate
25 at least the second (and third if used) milling tools, and
usually a small additional portion of the bottom hole assembly.
The prudent driller typically makes the rat hole deep enough to
assure that the subsequent drill bit will pass cleanly through
the window. A typical rat hole is four or five meters deep and
30 is not drilled deep enough to accept the entire bottom hole
assembly.

The bottom hole assembly embodiment of FIG. 1 permits the
exertion of directional control over the milling and drilling
process. As discussed in RE 33,751, the offset of the cutting
35 tool from center, created by the bend angle of the bent housing

1 Further cutting of the rock formation outside the casing is
usually undesirable since the conventional casing mill is
designed specifically for cutting casing and is not particularly
5 well suited for drilling formation. Certainly the milling tool
would not be run into the formation more than fifteen meters
beyond the bottom of the window, far beyond the usual depth of
the rat hole. The casing mill wears rapidly in the rock
formation and is not suitable for drilling to the next liner
10 hanger point or true bottom of the well. At the point where a
rat hole has been formed, a conventional casing mill would be
withdrawn from the borehole and a conventional drill bit run in
for drilling rock formation outside the casing. The conventional
drill bit is not particularly well suited for milling casing and
would, typically, have unacceptable wear when so used.

15 In practice of this invention, however, the same drag bit
is used for milling through the casing and for drilling rock
formation to the next liner hanger point, for example. This is
typically more than fifteen meters beyond the sidetracked well
bore, much further than a traditional rat hole. As the dual-
20 function bit drills further into the formation the downhole motor
and bent housing assembly are used for steering to provide
directional control of the borehole being drilled. Alterna-
tively, steering may be provided by way of a steerable bottom
hole assembly on a rotating drill string.

25 In an embodiment with inserts as described and illustrated
in Fig. 3 are employed, when the inserts 16 have had the outer
material layer designed to mill the pipe casing worn away, the
second material layer 23 designed to drill formation is exposed.
The drilling of rock formation continues due to the rotary
30 application of the combined milling and drilling tool to
formation for a desired distance beyond the length of a
conventional rat hole. The drilling of formation can continue
without requiring the removal and/or replacement of the drilling
assembly until the next liner hanger point is reached by the

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1 wear away in the rock formation and the PCD inserts take over the drilling operation.

5 In an exemplary sidetracking operation, a window may be cut in a 9-5/8 inch casing and about 100 meters of hole drilled with an 8-1/2 inch drilling bit. A 7-1/2 inch liner is then cemented in the sidetracked hole, and a 4-1/2 inch bit used to drill further into the formation. Traditionally, two bits are used for milling the casing and drilling the 100 meter extension. With this invention, a single dual function drag type bit with PCD
10 inserts may be used for both milling a window through the casing and extending the hole 100 meters or more through the formation for placement of a liner.

In another embodiment, a layer of PCD may be formed on a carbide body. This is covered with a layer of titanium nitride
15 or titanium carbonitride which is used as the material for milling the steel casing.

Still another embodiment of insert, as illustrated in FIG. 7, has what amounts to two cutting edges. A carbide body 24 has a layer 23 of PCD on an end face. A layer of carbide may be
20 formed or brazed over the PCD if desired, or the diamond layer may be used for milling the steel casing. In this embodiment there is also a ring or band of PCD formed in a circumferential groove around the cemented tungsten carbide body. As this embodiment of insert is used, the layer of PCD on the front face
25 may wear and the additional band of PCD then serves as a second cutting edge. If desired, the edges of the insert may be beveled at the rake angle so that the second cutting edge is exposed at the beginning of drilling.

The inserts described and illustrated herein have each
30 featured a cylindrical cemented tungsten carbide body with layers of material for milling casing and drilling rock formation on one end face. It will be apparent to those familiar with drag bits that other types of inserts may be employed. For example, one popular type of PCD insert has a disk-like carbide substrate
35 with a layer of PCD formed on one face. This disk of carbide is

1 CLAIMS

1. A method of drilling a portion of a well comprising the steps of:
5 introducing a dual function tool into a well bore;
 milling a window in well casing in the well bore with the dual function tool, including drilling a rat hole in formation adjacent to the well bore; and
 continuing to drill formation beyond the end of the rat hole
10 with the same dual function tool.

2. A method of drilling a portion of a well comprising the steps of:
 introducing a dual function tool into a well bore;
15 milling a window in well casing in the well bore with the dual function tool; and
 continuing to drill formation adjacent to the well bore with the same dual function tool until at least an entire bottom hole assembly connected to the dual function tool has passed through
20 the window in the well casing.

3. A method of drilling a portion of a well comprising the steps of:
 placing a sidetracking whipstock in a well bore;
25 introducing a dual function tool into the well bore;
 milling a window in well casing adjacent to the whipstock with the dual function tool; and
 continuing to drill formation adjacent to the well bore with the same dual function tool beyond a location where the whipstock
30 has an influence on the direction of drilling by the dual function tool.

1 continuing to drill formation adjacent to the well bore with
the same dual function tool to the true end of the well.

8. A dual function bit for milling casing in a well bore
5 and for drilling rock formation outside the well bore comprising:
a drag bit body; and
a plurality of inserts in the drag bit body, each of the
inserts comprising:

an insert body,
10 a layer of polycrystalline diamond material on a
cutting face of the insert body, and
a layer of softer material over the layer of
polycrystalline diamond, the softer material layer having
a sufficient hardness and thickness for milling through
15 steel casing in a well bore.

9. A dual function bit according to claim 8 wherein the
layer of softer material is selected from the group consisting
of polycrystalline cubic boron nitride, titanium nitride,
20 titanium carbonitride, tungsten carbide or cemented tungsten
carbide.

10. A dual function bit according to claim 8 wherein the
layer of softer material comprises cemented tungsten carbide.

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11. A dual function bit for milling casing in a well bore
and for drilling rock formation outside the well bore comprising:

a drag bit body; and
a plurality of inserts in the drag bit body, each of the
30 inserts comprising an insert body having a layer of
polycrystalline diamond material on a cutting face of the insert
body for drilling rock formation; and

a plurality of cemented tungsten carbide cutters mounted on
the body in parallel with the inserts for milling steel casing.

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Application No: GB 9903332.6
Claims searched: 1

Examiner: Dr. Robert Fender
Date of search: 10 May 1999

Patents Act 1977 Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): E1F

Int Cl (Ed.6): E21B

Other: Online: WPI, EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2304760 A (TIW CORPORATION)	1
X, E	WO 98/13572 A1 (BAKER HUGHES INCORPORATED)	1
A	WO 98/34006 A1 (WEATHERFORD/LAMB)	-

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.

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A Document indicating technological background and/or state of the art.
P Document published on or after the declared priority date but before the filing date of this invention.
E Patent document published on or after, but with priority date earlier than, the filing date of this application.